Bagasse as a Fuel for Combined Heat and Power (CHP): An Assessment of Options for Implementation in Iran

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Abstract

With over one hundred years of commercial cultivation, sugar cane is one of the most valuable agricultural botanical resources in the World. This position is not only based on production of sugar from sugar cane but also it is, to a great extent, as a result of the increasing importance of sugar cane by-products and side industries. Furthermore, with the advancement of science; awareness of inharmonious growth of materials and energy consumption, and the desire to minimize the negative impacts of industrial pollutants and materials, the scope for using sugar cane is still developing rapidly.

Bagasse, molasses and filtered mud are the most important by-products in the process of production of sugar from sugar cane. Among these by-products, bagasse is both a biomass resource for producing energy and is one of the most important agricultural wastes, which can be used in different side industries. Therefore, it was chosen for study in this research as it offers considerable potential as a source of energy.

Bagasse is often used as a primary fuel source for sugar mills; when burned in quantity, it produces sufficient heat energy to supply all the needs of a typical sugar mill, with energy to spare. To this end, today a secondary use for this waste product is in combined heat and power plants where its use as a fuel source provides both heat and power. With a suitable energy production technology, bagasse can be used as a fuel in CHP for high efficiency energy generation. Today, with regard to the low efficiency of traditional methods, the high cost of disposal of waste materials and environmental pollution, the use of modern methods such as anaerobic digestion for the production of biogas has increased. The collected biogas from the process of anaerobic digestion provides a renewable energy source similar to natural gas, but with less methane and lower heating value, that is suitable for use in CHP plants.

In this research, a comparison with different bagasse energy production technologies leads to the selection of anaerobic digestion as the most suitable for use in Iran. Then a typical biogas CHP is assumed, and the biogas system is designed. Finally, the potential for the development of biogas CHP plants with bagasse in Iran is addressed through a study of the economic and environmental aspects.

Keywords: Anaerobic Digestion, Bagasse, Biogas, Biomass, CHP, Sugar cane industry

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<u>Contents</u> **<u>Page</u>**

Contents	**Page**

Contents	**Page**

Contents **Page**

Contents | **Page**

Contents **Page**

Appendix II: Published Paper

List of Figures **Page**

List of Figures **Page**

List of Figures **Page**

List of Tables | **Page**

List of Tables **Page**

Abbreviations

δ^{*}	Biogas density	kgm^{-3}
η_e	Electricity efficiency	%
η_{th}	Thermal efficiency	%
η_{VP}	Efficiency of the preparation tank pump	%
ρ_{b}	Bagasse density	kgm^{-3}
ρ_{G}	Substrate density	kgm^{-3}
ρ_s	Liquid manure density	kgm^{-3}
ρ_{w}.	Water density	kgm^{-3}
A_{BR}	Surface of the bioreactor, where heat is lost	m^2
$C_{p,SU}$	Substrate specific heat capacity	$J(kg°C)^{-1}$
C_w	Specific heat capacity of the heating medium	$J(kg°C)^{-1}$
D_a	Diameter of aeration pipe	m
D_{AG}	Outer diameter of agitator	m
D_{BR}	Diameter of bioreactor	m
D_{HP}	Diameter of the heating pipe	m
D_{PT}	Diameter of preparation tank	m
D_{Res}	Diameter of residue storage tank	m
E	Nominal capacity of the electrical power of the CHP	kW
E_{biogas}	Specific biogas energy	kWm^{-3}
E_e	Capacity of the plant to deliver electrical energy	kW
E_{th}	Capacity of the plant to deliver heat	kW
f_{VPT}	Factor to increase the preparation tank	-
f_{VBR}	Factor to increase the bioreactor volume	-

f_{Vres}	Factor to increase the residue storage tank	-
h_{BR}	Heat transfer co-efficients	$Wm^{-2}°C^{-1}$
H_{BR}	Height of the bioreactor	m
H_{PT}	Height of the preparation tank	m
H_{Res}	Height of the residue storage tank	m
H_s	Height of the bagasse reservoir	m
K_{BR}	Polystyrene heat transmission co-efficient	$W(mK)^{-1}$
L_{HP}	Length of the heating pipe	m
L_s	Length of the bagasse reservoir	m
n_{AG}	Revolutions of an agitator	rpm
Ne_{AG}	Newton number of an agitator	-
$\dot{M}_b$	Mass rate of bagasse	Mgd^{-1}
$\dot{M}_{BR}$	Produced flow of biogas	Mgd^{-1}
$\dot{M}_{oil}$	Flow rate of ignition oil	Mgd^{-1}
$\dot{M}_s$	Mass rate of substrate	Mgd^{-1}
P_{AG}	Power consumption of the agitator	kW
P_c	Power consumption of the air compressor	kW
P_{SC}	Power consumption of a bagasse conveyor	kW
Q_{BR}	Heat losses of the reactor	kW
Q_N	Necessary heat	kW
Q_{SU}	Required energy to heat the substrate	kW
Q_{supply}	Flow rate of heating medium in the pipe	m^3h^{-1}
Q_v	Total heat loss	kW
t_{AG}	Time of operation of an agitator	$minh^{-1}$

t_{BR}	Residence time in the bioreactor	d
t_{BRI}	Time for discharging the reactor content	h
t_E	Residence time in the residue storage tank	d
t_{RPT}	Residence time in the preparation tank	d
t_{sc}	Running time of the bagasse conveyor	hd^{-1}
T_A	Lowest outside temperature	°C
T_{BR}	Fermentation Temperature	°C
v_a	Velocity of air in the aeration pipe	ms^{-1}
$\dot{V}_a$	Air Flow Rate	ms^{-1}
v_{BRI}	Velocity in the discharge pipe	ms^{-1}
$\dot{V}_c$	Compressor throughout	Nm^3h^{-1}
v_H	Flow rate of heating medium in the pipe	ms^{-1}
V_a	Volume rate of air in the aeration pipe	Nm^3h^{-1}
V_{BR}	Volume of bioreactor	m^3d^{-1}
$\dot{V}_{BR}$	Biogas flow rate	ms^{-1}
$\dot{V}_{Res}$	Feedback from the residue storage tank	m^3d^{-1}
V_c	Volume of the compressor pressure vessel	m^3
V_{Res}	Volume of the residue storage tank	m^3
V_{Gh}	Volume of the gasholder	m^3
$\dot{V}_p$	Volume rate of the preparation tank pump	m^3h^{-1}
V_{PT}	Volume of the preparation tank	m^3
V_s	Volume of the bagasse reservoir	m^3
$\dot{V}_{SC}$	Volume flow of bagasse in the conveyor	m^3h^{-1}
W_s	Width of the bagasse reservoir	m